ART. VII. — THE MECHANICS OF MODERN NAVAL WARFARE.

THERE is an astonishing discrepancy, of late, in the relative progress of military science and the science of naval warfare; and the advantage is with the latter. How many new methods, even, (for it would be difficult to recount any new principle,) have been introduced into the military art within the last century? Various sorts of rifled ordnance, giving longer range; new explosive projectiles; the new device of hasty field fortifications, taught by the earthwork fighting of the Southern Rebellion; some improvements in the details of quartermaster and commissary departments, and in the transportation of troops, by the use of railroads in war; perhaps, also, bolder experiments with movable infantry columns, as of Wellington in the Peninsula, the Allies in the Crimea, and Sherman in Georgia, though they, even, were not strictly unprecedented; — these, and such as these, make up the record. We find ourselves, accordingly, prosecuting war on substantially the same basis as of old, with the same tactics and logistics, as well as the same strategic principles. We must travel back to the introduction of gunpowder before we find a revolutionary era. Our campaigns are modelled on Napoleon's, Frederic's, nay, on the campaigns of Marlborough, Turenne, and Gustavus Adolphus. We try recent exploits by ancient standards, and feel safe only when stayed up by the canons of tried and admitted authority.

Not so, however, with modern naval science. It has been, not changed, not improved, but absolutely revolutionized within half a century. During the last fifty years, and under the observation of most of those who read these pages, maritime warfare has become a thing so essentially different from what it was before, that the old heroes of the quarter-deck — Blake, De Ruyter, Van Tromp, Vernon, and even Jervis, Duncan, and Nelson — would not now, if recalled to earth, recognize their own profession. These changes, few in number, are yet fundamental. The science of ship-building and the science of ship-fighting have both been reconstructed since the dawn of our century. The whole motive-power of war-vessels is

changed; so is the theory of attack and resistance. New principles of harbor defence, and of the protection of coast-lines in maritime countries, all over the world, have been discovered. And as for ocean combats, Trafalgar or the Nile might as well be as old in history as Salamis, so far as their scientific lessons will avail in future contests. Indeed, it is questionable whether the *ναυμαχία* of the classical Greeks be not a more profitable study, in some regards, than the deeds of the doughty admirals of Spain and Holland. Now, at all events, our new science begins to aim at the points sought by the old, though from a different quarter. We *ram*, in fighting, if nothing better can be accomplished, as the ancients did with their galley-beaks, and we protect our motive-power from hostile missiles, as the Greeks and Romans shielded their banks of oars.

Moreover, the phenomena of modern naval warfare have entirely disordered the prestige and relative positions of leading maritime nations, and assigned them a new relative rank. While the advance in military science has been deliberate and tolerably uniform the world over, the naval changes have been comparatively sudden, and thorough. Accordingly, it is the developments of naval science which have chiefly affected the comparative relations of every state in Europe and America which has a coast-line. This is especially true of Russia, England, France, Sweden, Italy, and the United States; and the fact may serve to account, mechanically and practically, and perhaps quite as well as the hypothesis of the Palmerstonian policy, for the recent extraordinary decline of Great Britain in prestige. England was once, but is no longer, the mistress of the seas. There lies the key of her modern state policy.

So vast is the influence exercised on the fortunes of empires and commonwealths by the progress of naval warfare, that we propose to trace the introduction and influence of its chief new features, touching, as exclusively as may be, on the main points, without trying to describe tentative, unsuccessful, or merely auxiliary processes.

The revolution which has taken place during the last fifty years in the science of naval warfare, by the introduction of

entirely new systems of naval construction and armament, has been wrought by three great agents. These are, first, horizontal shell-firing from the artillery of war-vessels; secondly, the use of steam, or, more strictly, of the screw-propeller, as a naval motor; thirdly, the application of iron armor to prevent the entrance of hostile shot and shell. Perhaps submarine warfare with torpedoes might properly be added.

Each of these three prime agents, *shells*, *steam*, and *iron armor*, on its appearance, instantly produced radical changes in the form and battery of war-vessels. The introduction of shells, for example, diminished number in naval artillery, but increased calibre. Frigates with two tiers of heavy ordnance at length took the place of those huge gun-boxes called line-of-battle ships. Long before the beginning of the Southern Rebellion, this latter species of naval craft was, in the eyes of good judges, obsolete. But the correctness of the theory which rests on the use of the large-calibre shell-gun was never so pointedly demonstrated to popular sight as by the late action between the Kearsarge and Alabama, when the missiles from the former's eleven-inch smooth-bores made great chasms in the side of her opponent. Again, the introduction of steam into war-vessels makes naval movements independent of the fickle wind, and gives them mechanical precision. It was first erroneously looked upon as auxiliary to sails; now the sails are but auxiliary to the screw-propeller. It is almost needless to say that the use of steam as a motor has now become an essential element in the construction of all war-vessels whatever; at one swoop overthrowing, accordingly, the rules and laws of warfare which, less than half a century since, governed the navies of the world. Sails may continue to be used in ordinary cruising, from motives of economy; and even when a vessel is under steam high speed is not always required. Nevertheless, high speed is a *sine qua non* in times of exigency. The naval warfare of the future has been reduced, apparently, by the introduction of iron-clads, to two classes of vessels: first, impregnable and tremendous engines of war, to cover with impenetrable shield a nation's coast and harbors, and to batter down, if occasion requires, the coastwise defences of its enemy; secondly, light ocean guerillas, fleet-winged cruisers, scouring the seas at

the highest speed, and holding commerce at their mercy. The former are represented by such vessels as the Dictator or the Bellerophon; the latter by the Alabamas, the Madawaskas, and the Shenandoahs.

It will be readily seen, however, that, while defining thus distinctly the three agents which have wrought a revolution in modern naval warfare, it will be advantageous, in discussion, no longer to separate them in fixed phrases, as it is often difficult to tell where the influence of one ends and that of another begins. This is especially true in considering the problem of operating enormous guns by mechanical means within shot-proof structures. We propose to show, farther on, and at as much length as possible, how this latter problem will affect the power, and consequently the foreign policy and political destiny, of all maritime nations.

Artillery, and of course gunpowder, were first introduced into war-vessels during the reign of Edward III., about 1350. For five hundred years, however, naval construction did not advance so much as might have been expected from this radical change in weapons. Only, by degrees, ships were divested of much of the unwieldly top-hamper which was necessary in the hand-to-hand conflicts of the Middle Ages, and shorn of masses of the ridiculous decoration, whereof some traces are still observable in the poops and figure-heads of the old-style sailing war-craft. During this long period, the changes introduced in both the modelling and the management of vessels were only such as followed from practice in navigation, — the shape, dimensions, and method of handling the sails being improved with the lapse of time and growth of experience. Not until 1842, with the introduction of the screw-propeller as a naval motor, was any radical change effected. It is said that even sailing on the wind was not generally practised until the reign of Henry VIII., and, without the knowledge of this art, naval evolutions must have been of the rudest character, not enjoying nearly the precision with which the Greeks and Romans manœuvred their war-galleys. One of the first authentic applications of mensuration to find the displacement and draft of a vessel is contained in Pepys's diary for May 19, 1666. Now this would seem to indicate that ships had previously been built by guess-

work. Yet they had been built somehow since the Ark, and constructors must have employed some means to get at so essential and so easily calculated a point as the approximate displacement and draft of a vessel. Yet the well-informed writer on the subject of Ship-Building in the Encyclopædia Britannica thinks Mr. Deane was the first to employ calculation in ship-building. He says: "This gentleman appears therefore to be the first who applied mathematical science to naval architecture in this country." That a discovery so obvious as that made by Archimedes during his reflections in his bath, namely, that a body floating in a fluid displaces its own weight of the fluid, should not have been applied, however unskilfully, to ascertain the displacement or volume of the proposed immersed portion of a vessel, and thus arrive at the draft of water and capacity, seems too incredible to be true. From these brief illustrations, therefore, it will be seen that, however interesting the literature of naval construction during the five centuries preceding our own, it contains very little record of radical progress; and, as even that little has ceased to be of moment to us now, owing to the revolutionary changes already mentioned, we may leap this historic field at a bound.

The most marked event in naval construction in modern times, prior to the introduction of steam, was the American practice of reducing the number of naval guns, and increasing their weight. This is the secret of the naval victories of the war of 1812. Our vessels were constructed with the idea of crowding the battery-power of a full line-of-battle ship into a frigate. This idea America has persistently pursued up to the present moment, and she has been gradually followed by other maritime powers. As a result of this system, in the action between the British 44-gun frigate Guerriere and the American 44-gun frigate Constitution, the former was defeated in a very few minutes by the superior battery of the latter, aided doubtless by superior gunnery practice. The weight of the Guerriere's broadside was 517 pounds; that of the Constitution, 768 pounds. Precisely the same result followed between the British Macedonian and the American United States. The ships were rated the same. Yet the former's broadside was

528 pounds, and that of the latter 864 pounds. Indeed, in those days, the weight of the broadside of an English 100-gun line-of-battle ship was about 1,260 pounds, less than one third more than that of the United States 44-gun frigate.* This superiority in American wooden ships has, according to the London Times, ever since been maintained.

At this point comes in the influence of shell-firing. The destructive effect resulting from throwing shells, instead of balls, into wooden ships has been so marked, that more than one claim for the merit of the adaptation has been made.† But it is difficult to mark the line between "vertical" shell-firing, i. e. that of missiles projected from mortars, and "horizontal" shell-firing, or the projection of shells from guns. For example, under which head shall be put the shell practice against Charleston from General Gillmore's guns on Morris Island, in any accurate classification? The high angle from which these guns were fired would hardly entitle them to be cited under "horizontal" shell-firing. At all events, the naval warfare of the last five years has demonstrated the change which long ago was prophesied as the result of the introduction of this modern artillery practice. Sloops, with but *one* tier of guns, and yet with a displacement equal to that of an old line-of-battle ship, and a proportion of steam-power greater than has ever been placed in steam-vessels for sea-going purposes, are the kind of war-vessels we see now building. Just before the general introduction of iron-clads, America and England had each a series of powerful wooden vessels, which illustrated the point of concentration and weight of battery. The battery of the well-known Victoria, an English 121-gun ship, is far inferior to that of our vessels of the Minnesota class, of 44 or 52 guns, in range, in accuracy, and in power. And in spite of the former's superiority in size of ship, number of guns, and num-

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* James's Naval History.

† The French General Paixhans is generally, but erroneously, regarded as the originator of horizontal shell-firing; the real inventor is Colonel Bomford of the American Army, who planned the Columbiad. Sir Howard Douglas (Naval Gunnery, Art. 310, 311) discourses on the anticipated effects of employing shells; and a letter of General Paixhans, published in the *Moniteur* of February, 1854, on the burning of the Turkish fleet at Sinope by the Russian shells during the Crimean war, shows that this was the first action in which his shell was employed.

ber of men, the victory, in a contest between a representative American frigate and a representative British line-of-battle ship, other things being equal, must terminate in favor of the American.*

It was the terrible destructiveness of heavy shells, anticipated at the outset by artillerists, which caused attention to be turned to the necessity of providing iron plates for ships. From the moment that shells were introduced, the collected wooden navies of the world began to lose their value. To test the question, the Admiralty anchored the frigate Hussar off Shoeburyness, in the fall of 1862, and threw at her concussion-shells from a shell-gun. Every one of them went into her and set her afire, and very soon she burned to the water's edge. Heavy shells go through wood like card-board, and fire it with astonishing facility. Discipline is almost as difficult to preserve, under such circumstances, as in a battalion enfiladed by a flank fire. And, in any case, it distracts attention from manning the guns. The larger the ship and the more numerous her crew, the more terrible and demoralizing is the slaughter; for, pent in the narrow wooden walls, with no chance of retreat, the seamen exposed to a shell-fire are literally slaughtered.† And this is the way the intro-

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* Our heavy frigates of 1854 were the Merrimack, Minnesota, Wabash, Colorado, Roanoke, and Niagara. The first five were of about 4,000 tons' displacement, but were intended to carry a battery of forty-two 9-inch Dahlgrens, and two 11-inch Dahlgren pivots, both of which can project solid shot or shells.

The Minnesota's armament during the war consisted of one 8-inch rifle pivot, one 11-inch Dahlgren pivot, forty-two 9-inch Dahlgrens in broadside, four 6.4-inch rifles, and four Dahlgren howitzers. The weight of her broadside of solid shot was 2,606 pounds; that of her broadside of shells was 2,123 pounds. Her complement of men was about 650. (See Ordnance Report for 1864.) The displacement of the Niagara was over 5,000 tons, and her original battery was twelve 11-inch Dahlgrens, so mounted as to be used on either side. These celebrated vessels were regarded as having reached the consummation of horizontal shell-firing. Immediately after the famous visit of the Merrimack to Southampton, England commenced building a fleet of frigates to match ours, consisting of such vessels as the Diadem, Mersey, and Orlando. The Victoria, the first of the English line-of-battle ships, was of 5,083 tons' displacement, and carries one hundred and twenty-one guns, as follows: lower deck, thirty-two 8-inch shell guns; middle deck, thirty 8-inch shell guns; main deck, thirty-two 32-pounders; upper deck, twenty-six 32-pounders, one 68-pounder pivot; weight of broadside, about 2,500 pounds; total complement of men, 1,150.

† "We can only feebly imagine the scene after the explosion, under these circumstances, of a few Armstrong segment-shells, scattering deadly fragments of thick

duction of heavy shell-firing has revolutionized warfare. It has quietly dismissed to oblivion great and expensive navies, and sent them to rot in dock-yards, or to be employed in the pacific work of transporting troops or supplies. Two elements, however, here come into play. The first is the heaviness of the ordnance, on the principle of concentration; and the second, the nature of the projectile, i. e. the explosive shell. It will not do to throw light shells in these days of iron-clads.* It is a little singular to note the repeated lessons on the concentration of destructive artillery which America has taught older nations. They began, as we have explained, with the affair of the Constitution and Guerriere, and were manifest all through the war of 1812. Again, in 1854, our heavy frigates taught the same lesson pacifically, and then England heeded it. The third instance was in the battle between the American ship Kearsarge and the English† ship Alabama. This was the first battle ever fought between two vessels in which horizontal shell-firing was employed. And Dahlgren's 11-inch shells sent his opponent to the bottom. The firing of the wooden fleet in Hampton Roads by the shells of the Merrimac had already

iron on every side. Our old wooden three-deckers have been not inappropriately designated "floating charnel-houses," and such they would inevitably become in a few minutes after the commencement of an action, with our modern appliances for the destruction of human life. No sane or unprejudiced person, we suppose, would trust the honor of the nation to these picturesque and fine old ships, which heretofore have been our salvation and our glory." — *The Quarterly Review*, January, 1864, article on "Guns and Plates."

* On a trial of 130-pound shells against the Warrior plate, the Report of the British Committee on Ordnance says: "Heavier guns, capable of being used with much larger charges of powder, must be adopted before horizontal shell-firing can be looked upon as very destructive to a ship of the Warrior class."

† It is remembered, of course, that the Confederate government had bought this ship of the English; but we speak of it in a mere professional point of view, as illustrating a system of national construction and handling in which, naturally, we cannot use the term "Confederate." This ship being English from truck to keelson; every spar, every inch of canvas, every rope in her, English; built in England; manned by a greater proportion of English native-born subjects than many ships in the Royal Navy; her crew picked, as usual, in English fighting vessels, from men who had been on the English training ships; her artillery all English; and the mode of manœuvring and fighting English; — these things being so, the fact that the Alabama was not flying the English colors is a point for political historians to consider, but it has no scientific bearing. Had the contest resulted otherwise than it did, the glory could not have been robbed from England by the flaunting of Confederate colors.

been decisive that the chief reliance of maritime nations must be in iron-armored ships.

But what shall be said of the revolutionary work of steam? One sentence will tell the story as plainly as a quarto volume. The screw-propeller has changed, at once and forever, the entire motive-power of war-vessels. We attribute this revolution to the "screw-propeller." For many years after the introduction and wide-spread use of steam in commercial craft, war-ships did not use it. The reason was twofold; — first, because of the disarrangement which the huge paddle-wheels must have made with the battery and also with the use of sails; and secondly, because of the fatal exposure of machinery to an enemy's shot, which rendered the paddle-wheel vessel liable to utter helplessness from a single discharge. The honor of inaugurating the new era was reserved for Captain John Ericsson, and through him for America.* The propeller he introduced is, to the present day, with some slight alterations which do not materially affect its efficiency, the one universally employed. Attempts previous to his seem to have been little more than a repetition of the Archimedean experiment of revolving a submerged worm, or helix, attached to a vessel. A complete master of the physical laws involved in the action of oblique surfaces moving in water, and adding thereto high scientific and professional attainments and great mechanical skill, Ericsson was able to plan his propeller, and all its attachments of steam-engines, with perfect accuracy. The entire contrivance worked precisely as predicted, and with no alteration, — all as laid down by him on his drawing-board. We are not, accordingly, to look for any radical improvement on the propeller in future.

The United States steamer Princeton was the first war-propeller ever built. And so admirably well was every part of her machinery planned and constructed, that, when it had worn out one hull in service, a new hull was provided. The Princeton was launched in April, 1842, — a monument of engineering skill. Not only was she the first war-propeller ever built, and the one on which, with slight modifications in de-

* For proof of this point, see Bourne on Screw Propellers; also, Encycl. Britannica, Vol. XX. p. 639.

tails, the vast screw navies of the world have been constructed, but her engine was the also first *direct*-acting engine, that is, one in which the engine seizes directly hold of the shaft, without the intervention of gearing. She was, finally, the first war-vessel which had her entire steam-machinery placed below the water-line, out of the reach of shot. The Greeks and Romans understood the importance of keeping the motive-power of their galleys well protected. They interposed great casemates, so to speak, for the protection of the oarsmen. No manœuvring in naval combats, from those early days to ours, was comparable to that which one reads of in the sea-fights from Salamis to Actium. Ships never were handled so quickly in actual combat under sails as they were under oars; but, above all, the motive-power was never so well protected. After the lapse of so many centuries, we again equal and surpass the ancients in both particulars. The ingenious contrivance of faking the chain-cable along the sides of the ship, in combat, at Forts Jackson and St. Philip, and again more famously on the Kearsarge, is well known. The Princeton would have had no need of such protection, for her steam-machinery was all below the-water line. A departure from this principle, in the case of all our wooden screw ships built before and during the war, suggests the painful possibility of utterly ruining their availability by a single well-directed shot.

It was with inconceivable reluctance that the British Admiralty took up the project of a screw navy. They had rejected Ericsson's invention in 1837, when he had not only offered them his propeller at the outset, but had demonstrated its value by trials with it upon the Thames. The eagerness with which the United States first seized the new instrument, and, more particularly, the alacrity with which France afterwards adopted it, actually forced the English government into building screw ships. The renovation of the entire British Navy, and the substitution of steam for sails, was at length completed, at great expense, in 1859. While we were not quite as slow as the English in this matter, our Navy Department (as it now and then will) in at least one matter vied with them in dulness; for after the propeller was an established success, the British were building sailing frigates, and we, lumbering paddle-wheel frigates.

Vast numbers of screw steamers now figure on the British Naval Register. Nearly all of them, however, — nearly all, at least, of large size, — with the notable exception, of the Mersey class of frigates, built expressly to compete with our frigates of the year 1854, after the visit of the Merrimack to Southampton, are sailing vessels, altered to receive the propeller. In some cases these were lengthened, in others the sterns were reconstructed; in others, both alterations were made. Their wood was almost indestructible, being, in the chief parts of the ship, either teak or live-oak; and hence, when the propeller was put in, they were, for strength and soundness, quite as good as new. Still, the iron-clad now takes the place of these old-fashioned, heavy wooden vessels designed for defence. The work now devolving on wooden ships is different. Fighting each other, assailing commerce, and transport service are the duties to which the wooden fleets of the world are assigned; and even for depredations on commerce and for transport service they are now, or soon will be, behind the times.

So, as we have seen, does steam sweep away fleets and systems of warfare, and render the accumulated naval power of nations of little effect. To show its enormous influence, it will be sufficient to instance a single country, England. She ruled the seas of yore by her trained seamen and by her skill in naval manœuvre. Her models were not better than those of rival nations. Indeed, her ships were not as good as those of France or Holland, throughout the eighteenth century. But her seamen were the best in the world.* At one fell swoop this prestige is gone, since mechanism now performs the functions which once required men. Astonishing as this fact is, — and it is a fact already admitted by British writers, — it is not less so than one other, which shows how strategic position is affected by this revolution in naval warfare. Of old, Britain, safe in her "salt-water girdle," and surrounding herself with a cordon of well-manned navies in the Channel, in the Irish Sea, in the North Sea, and in the Atlantic, laughed at attack. The reminder of Cymbeline's Queen to her royal spouse was always comforting enough to the descendants of their subjects: —

* See Alison, Vol. II., on the battle of Trafalgar.

> "Remember, sir, my liege,
> The kings your ancestors, together with
> The natural bravery of your isle; which stands
> As Neptune's park, ribbed and paled in
> With rocks unscalable, and roaring waters;
> With sands that will not bear your enemies' boats,
> But suck them up to the topmast."

This notion of the availability of the Channel as a line of defence has always been a favorite one with Englishmen, from the days of the Druids to the days of the Guelphs. Now, however, it has been rudely shocked, and perhaps entirely driven out. "The introduction of steam as a propelling power of ships," says a good authority, "has been regarded by some persons as wholly revolutionizing all previous warlike theories. The Duke of Wellington adopted this idea; but Lord Palmerston, above all others, has maintained that the new system *has almost annihilated the Channel as a line of defence*. . . . The Report of the Defence Commission adopted, though with less positiveness, the Premier's idea." *

We would gladly pause upon some of the points already suggested, as well as upon matters collateral. But we are fully aware that all the popular interest now attaching to the "mechanics of naval warfare" concentrates upon the great iron-clad question. At this moment this discussion is pushed with extraordinary vigor in England and France. And, indeed, it well may be, for it is of most momentous importance to the welfare of those countries. In this country, having chosen our system long since, and being wedded to it, finding it true in the hour of exigency, for us the period of harassing uncertainty is past; but in England no scientific question in the whole realm of warfare gets so much and so earnest discussion as this. Within a twelvemonth, probably more than a thousand different articles, of one sort or another, on this subject, have appeared in public there, from the laborious volume to the newspaper paragraph. To this subject, therefore, we will devote as much space as possible.

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* North British Review, August, 1863. When this startling theory of the loss of the Channel as a line of defence was first propounded, Sir Robert Peel, as in duty bound, rigorously attacked it. But Lord Palmerston, in 1860, declares Sir Robert Peel to have originated and maintained it.

Armored vessels may be classified under two general heads; namely, broadside iron-clads, and monitors, or turreted iron-clads. The broadside iron-clad is a vessel of the ordinary form, distributing her guns along both sides of the ship, and having a cuirass of iron secured to her sides. The monitor is a vessel in which the battery, instead of being distributed, is concentrated in pivot guns, protected with a revolving shield or turret of iron, so arranged that, by turning it, the guns can be aimed in any direction. These, of course, are not definitions of the rival systems, but only partial descriptions of some of their most palpable differences. We shall see the other points of distinction in proceeding. The leading maritime nations of the globe now intrust their naval prowess to iron-clads built on one or other of these two systems. France, England, Turkey, and Italy have adopted the broadside system; the United States, Russia, and Sweden, the turret system.

To the turreted iron-clads alone can be properly applied the term *invention.* Merely cuirassing the sides of a vessel with iron armor — which is the only substantial difference between the broadside iron-clad and the old wooden ship it is designed to supersede — can with no propriety be called an invention. It was an ancient expedient to build the sides of war-vessels much thicker than those of commercial ships, and far thicker than mere strength required. The design was, as now with iron-clads, to furnish protection against an enemy's shot. Moreover, descriptions or drawings of very many ancient vessels still exist, in which the sides had been made by this process of cuirassing (for such it may be called) quite as impervious to the artillery then brought against them, as is the present iron armor of the famous La Gloire and Warrior to the most powerful naval guns in use at the time the latter vessels were constructed.* Or, to put the matter in other words, wooden

* James relates an engagement which took place just seventy years ago off the coast of Flanders, between the English ship Glatton, which was built of remarkably stout timber, and four French frigates and two corvettes, a brig and a cutter, — her fifty-six guns "in strong sides" being altogether too much for their two hundred and twenty. Blackwood's Magazine (November, 1860) says her captain "tumbled his old tub amongst them, taking their fire with comparative impunity, and knocking them about with his guns in a manner which astonished them." The French loss was severe; the English, none killed and only two wounded. And this, too,

armor was of old used instead of iron; and the fundamental idea of building vessels with sides strong enough to keep out projectiles is very ancient, perhaps coeval with naval artillery. The mere substitution of one protection for another, of metal rather than wood, however desirable, can hardly be called an invention; and even if it could, the idea cannot be ascribed to any constructor of our day. Sir Howard Douglass says that General Paixhans proposed the use of iron for this purpose about forty years ago. That officer was so impressed with the fearful havoc which one of his shells would create by exploding in a vessel, that, having made so terrible an offensive weapon, he set himself with equal alacrity to construct a defensive work sufficient to neutralize it. He accordingly suggested to the Minister of Marine the expedient of using iron plates thick enough to keep shells from passing through a vessel's sides.†

But a definite proposal for constructing an armored vessel was made, in 1841, by the late R. L. Stevens of Hoboken. His plan was to plate a vessel with iron four and a half inches thick. It was really, in substance, the introduction of the broadside iron-clad system. What might, under ordinary circumstances, have come of this vessel, no one can tell. Perhaps, at this

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though the 26-gun brig and 8-gun cutter got for a while a raking position under the Glatton's stem, where only musketry could reach them. James very properly attributes the victory to the Glatton's 68-pounders, the French only carrying 12- and 24-pounders. Blackwood adds, that "her armament may account for the damage to the enemy, but not for her own trivial casualties; that must go to the credit of stout oak or teak, against the cannon of those days."

Indeed, a little more than two hundred years ago, an official paper by one Gibson, in comparing French and English ships, says: "The French has the advantage to fight at a distance, and wee yard-arm to yard-arm. The like advantage wee have over them in shipping; although they are broader and carry a better saile, *our sides are thicker, and better able to receive their shott;* by this they are more subject to be sunk by gunn shott than wee." —*Encyc. Brit.*, Art. "Ship-Building."

† "The Comité Consulatif de la Marine at that time having caused the weight of an iron covering, and the capability of ships to bear the load, to be calculated, found that such armor could not be applied to line-of-battle ships of the lowest class, to frigates, or to smaller vessels. With respect to ships with three decks, the Comité stated in its Report, that the great displacement of these would enable them to bear the requisite weight, provided the quantity of artillery on the upper decks was diminished. . . . This inquiry led, however, to no attempt in France to cuirass ships of war, and the project was at the time abandoned, apparently as impracticable."

moment, our navy might have consisted of fleets of iron-clads, like those of France and England. Fortunately, Captain Stockton, through Ericsson, exploded the Stevens theory by one shot from his famous 12-inch gun. This shot, weighing 224 pounds, and behind which burned thirty pounds of powder, was fired against a 4½-inch iron target, equivalent to a section of the armor proposed by Stevens. The ball pierced the target, and, beyond, plunged through a sand-bank eight feet in thickness. How much farther it went is unimportant to say. The project of the armored ship was abandoned by our country, for a time.

Stevens's project had the merit of priority. The iron-clads afterwards built by the Emperor Napoleon accordingly lose even the merit of originality; while the English were yet one remove farther from a claim to invention, since they followed Napoleon. The first iron-clads used in actual warfare were the floating batteries built by Napoleon during the Crimean war.* These the English made haste to copy, but their copies were of the rudest description. The action in which the French batteries took part was the attack upon Fort Kinburn, in the Crimea. The fire to which they were subjected was distant and not very heavy, and the batteries formed a small part of the force which attacked those "dilapidated" works. Chambers's History of the Russian War says the English portion of the attacking squadron was six steam line-of-battle ships, seventeen steam frigates and sloops, ten gun-boats, six mortar-vessels, three steam tenders, ten transports, — in all, fifty-two

* The descriptions of these vessels tell us that the decks were of plank, resting upon 10½-inch beams, placed 1 foot 9 inches from centre to centre. The top sides were covered with 6-inch plank, over which, extending to three feet below the water-line, was a sheathing of wrought-iron plates, 14 feet long, 20 inches wide, and 4½ inches thick, each secured to the hull by 1¼-inch screw-bolts. They are barque rigged, well fitted with non-condensing engines and screw propellers, and can make, under steam alone, four and a half to five knots.† They are pierced for thirty guns, and mount from fourteen to sixteen sixty-eights.

Dimensions of two of the English batteries: —

	H. Power.	Length.	Exterior Breadth.	Depth.	Draft.
Meteor,	150	173	43.6	14.7	7.9
Thunderbolt,	200	186	48.6	18.6	6.6

† Major Delafield states that one of the French batteries of this class steamed at the rate of one and a half knots per hour.

vessels, carrying about fifteen hundred guns and five thousand troops of all kinds. The French supplied, besides the three *floating batteries*, seven ships of the line and several smaller vessels. It was against this combined attack with ordnance, much more numerous and powerful than it possessed, that Fort Kinburn yielded. The floating batteries engaged at a distance of seven hundred yards, and at that distance proved invulnerable to 32-pound shot with 10-pound charges, — the largest calibre which was mounted on the fort.

The affair at Fort Kinburn is chiefly to be remembered as being the first time that iron-clad vessels were employed in actual warfare. The batteries were La Devastation, La Lave, and La Tourmente. The action is sometimes adduced as a strong proof of the power of iron-clads; but examination shows that it demonstrated very little with regard to their capabilities as engines of war. The chief fact, indeed, which it proved was the impregnability of their batteries to 32-pounder shot, at the distance of about seven hundred yards. Nevertheless, they were regarded by professional writers in Europe as failures. And the result of the attack would doubtless have been different, as far as regards these floating batteries, had the Russian works been casemated or been built of earth, and furnished with guns of heavy calibre. As a matter of fact, the Russian cannon were all mounted *en barbette*, with no traverses, and, worst of all, were erected on a low site, commanded by the guns of the allied fleet. In one word, the affair is of chronological rather than of naval interest, its chief importance being to mark the opening of the iron-clad era.

On the 9th of July, 1860, the iron-clad La Gloire was launched at Toulon, giving form to the idea so many years before promulgated by Paixhans. There was, nevertheless, a fundamental difference between the idea and this application of it; for the attempt was now made, not to build a mere floating battery, a simple box of guns, but a swift, invulnerable ocean vessel. According to Admiral Paris, the body of La Gloire is modelled on the lines of the Napoleon, a famous line-of-battle ship of ninety-one guns, and is of equal displacement; but she carries a much greater weight than that vessel, and consequently draws more water. The battery of the Napoleon weighed

4,438 hundred-weight, while that of La Gloire weighs 3,276 hundred-weight, and her armor weighs in addition about 820 tons. La Gloire is 250 feet long, has 55 feet breadth of beam, and draws, when loaded, 27 feet of water. Her armor is four and a half inches thick, increased to five inches at the water-line.

The woodcut of La Gloire, which is prefixed to Admiral Paris's work, shows plainly that her designer happily did not permit himself to be trammelled by conventionalities and time-honored usages in ship-building. The cumbersome and useless figure-head, which less daring innovators would not have ventured to touch, had no sacredness for him. The bow is perfectly plain, and the stem inclines somewhat backward from a vertical line.* This feature in construction we suppose to have been adopted for several reasons; — to increase the ship's power as a ram; to dispense with unnecessary weight; and to render the task of bending and fastening the armor-plates at the bow much less difficult than had it been of the conventional shape. In like manner, the stern is of the simplest form; and, in a word, the hull of La Gloire has the air of being made for service, not for ornament. The same observation may be made of her rig. It is very simple, consisting of three masts, with very long mastheads, designed probably to give firm support to the topmasts, without their depending too much on the rigging. The bowsprit is a short, straight, stumpy affair, and can evidently be removed at pleasure. The usual elaborate head-gear, as we have said, is discarded. The whole design in the rigging is plainly to have as few ropes as possible to be shot away, and so endanger the action of the screw by fouling it. La Gloire is fitted with plain fore-and-aft sails, with the exception of the foremast, which carries square sails. We have described the rigging and sails of this vessel at some length, in order to indicate how completely naval warfare has become a mechanical problem. Sails will never again, in all probability, be used in a naval fight.

La Gloire is pierced, in the usual way, with twenty gun-

* This idea was doubtless a copy of the model inaugurated by Mr. E. K. Collins, founder of the Collins Line of American Ocean Steamships, in the Atlantic, Baltic, Arctic, Pacific, and Adriatic.

ports on each side, of which the lower edge is about six feet above the water-line, while the top of the bulwark is about fifteen feet above the same line. The steering gear is placed in an iron tower, pierced with lookout apertures, located on the upper deck just forward of the mizzen-mast. The engines are of 900 nominal horse-power, and probably can develop between 3,500 and 4,000 actual or indicated horse-power. Her maximum speed is said to be thirteen knots per hour; but this assertion we hold to be very questionable. The bunkers are said to be capacious enough to contain coal for five days' steaming at this alleged rate. As the consumption, of course, would be proportionally reduced at lower rates, it may be conceded that her coal capacity is sufficient for duty in European waters.

As the shape under water of La Gloire is the same as that of the Napoleon, it was obviously the intention, in designing the former vessel, to use the displacement saved by cutting down the vessel, by decreasing the weight of her masts, and so forth, and by the less weight of provisions required for a less numerous crew, (for La Gloire's crew is but 550 men, while that of the Napoleon is upward of 900,) for carrying the armor which covers the ship. But here we come to one of the difficulties which La Gloire, with other broadside iron-clads, has experienced. It is well known that the position of weights in a vessel exercises a great influence on its motion in a sea way. Safety may surely be compromised by an injudicious arrangement of weights. It may be readily imagined that a ship of the mid-section of La Gloire, overloaded with an enormous weight of armor spread over her nearly vertical sides, together with the weight of the battery, which is of course placed along the sides, will roll deeply. The weight of the iron cuirass, placed high above the water-line, raises the centre of gravity very much higher than the conditions of stability require. The centre of gravity of the weight of a stable ship is usually very near the water-line. In La Gloire it is some distance above that line, and much higher than in ordinary vessels, rendering her of necessity deficient in steadiness. It is true that the centre of gravity could be brought down to the required point by the use of ballast, which would counteract the top-weight of her armor. But, unhappily, it is as much as a broadside iron-clad can do to

stagger under the enormous weight of iron with which she is covered. There is no floating power left for ballast.

Another element which adds to the rolling motion is the momentum of the heavy weight attached to the sides of broadside ships, so far from the centre of motion. This causes the rolling to be much greater than the action of the sea would of itself produce. We, too, on this side of the Atlantic, have tested this truth by actual experience in the case of the United States steam-frigate Roanoke. That vessel was cut down to a level with the gun-deck ports, the hull plated for the greater part with $4\frac{1}{2}$-inch slabs, and three turrets mounted on her. Although it is said that the weights added do not exceed those removed, the rolling is much greater than it was formerly.* It is not, indeed, intended to assert that the rolling of broadside iron-clads will endanger their safety, or render them unfit to navigate stormy seas, but it will unquestionably expose their sides below the armor, even when the rolling is comparatively moderate, and so leave the ship open, after all, to a shot in the very point most needing protection.† And, again, even moderate rolling must render it very difficult to manage artillery, and seriously interfere with accurate gunnery. It would seem to be impossible, for example, for La Gloire, except in smooth weather, to use her guns at all, on account of the water rushing up to her ports, and into them too; for her ports are but *six* feet from the water. And even if the rolling motion be not so great as to prevent the use of the heaviest naval guns now mounted in broadside, it will certainly preclude the use of guns of the weight necessary to use large charges of powder with the present appliances for working them.‡ What is true of the French broadside iron-clads is, of course, true of the English, which were copied from across the Channel. Thus, for one example, the Warrior, which was the English La Gloire, although fitted with wide bilge-keels, rolls thirty-eight

* See Report of Captain Sands to the Secretary of the Navy.

† See Xavier Raymond's tables of the rolling of the French iron-clads in the *Revue des Deux Mondes*.

‡ The English have lately succeeded in working a 12-ton gun by the use of the Monitor carriage and friction gear. They are so delighted as to contemplate knighting the officer who had the shrewdness to appropriate this familiar American device.

degrees.* This point could be easily expanded and illustrated through an entire volume. But it is enough to show, as we have done, how in broadside iron-clads like the French La Gloire and the English Warrior, this defect of rolling seriously impairs their use both for offence and defence, alike as to the use of their own batteries and protection against an enemy's.

But the rolling, although a fatal defect in broadside iron-clads, is not the only fatal defect, or even the chief one. It is an utter impossibility to design a broadside iron-clad of respectable model, whose sides shall be covered with even the minimum thickness of armor, worthy to be called "impregnable" to existing service cannon, and which shall be fitted with the weight of machinery necessary to furnish the speed possessed by first-class men-of-war, — it is absolutely impossible, we repeat, to build a broadside iron-clad possessing these primary and essential qualifications, without constructing it upon dimensions wholly without precedent in ship-building before the day of iron-clads, the Great Eastern alone excepted. This necessity for unprecedented dimensions, on the broadside theory, scientific observers saw at the outset; and even could these enormous dimensions be reached, the attainment of impregnability against the modern ordnance, which was rapidly approaching perfection, must have been extremely problematical in the minds even of the warmest advocates of broadside iron-clads. To this must be added still another fundamental objection, — the difficulty of working in broadside such ordnance as is necessary to perforate the armor of adversaries. Even the ordinary European armor — four and a half inches of iron with twenty of wood backing — requires for its piercing guns of such calibre as can with great difficulty be worked in broadside. This knotty problem is still the subject of constant study in England, and has not as yet received satisfactory solution.†

Indeed, the broadside system of iron-clads is almost self-con-

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* Journal of the Royal United Service Institution. See Captain Selwyn's remarks on this point.

† Captain Ericsson, however, has at length designed, for this country, a broadside-gun carriage which, after severe tests with the 15-inch (20-ton) gun, is found to have complete control over it even in a sea-way.

demning and suicidal. It presents fundamental objections at the outset on the only three points which can possibly make iron-clads of any value, — available seaworthiness and good behavior, impregnability, and practical battery power great enough to destroy armored adversaries. To some extent these objections are removable as between broadside iron-clads themselves. But then they only substitute one species of equal warfare for another; and French and English iron-clads can contend now with absolute, but not relative, impregnability changed. So far as any comparative gain, any change of proportion in fighting power, is achieved, neither nation has much to boast; but when we come to compare the broadside iron-clads with the monitors, all these intrinsic defects become at once magnified to irreparable and ruinous blunders. We find that armor cannot be applied to broadside iron-clads sufficiently thick to resist modern ordnance. We find insuperable difficulties in mounting and working cannon at all suitable for iron-clad warfare. We find an inevitable heavy rolling, which not only makes good gunnery impossible on the one hand, but frequently exposes, on the other, the unarmed portions of the ship at each roll.

The simplest method of explaining the vulnerability of the heaviest broadside iron-clads ever constructed, is to take the two tables which we shall insert for this and kindred purposes, and then turn to any of the tables containing the most important experiments with guns against plates. It will be seen, by mathemetical demonstration and by recorded experiences, that targets fairly representing sections of the heaviest broadside iron-clads, either built or building, have been repeatedly shot through and through by artillery much less powerful than that used for years by our monitors. The armor of the Warrior proved impregnable to the 68-pounder of ninety-five hundred-weight, — the heaviest gun, at that time, in the British Navy. But the first $10\frac{1}{2}$-inch wrought-iron gun, fired with a 50-pound charge against this armor, sent a 150-pound shot through it as if it had been pasteboard; and the 13-inch wrought-iron gun crushed a hole in it nearly as great as one made by a shot two feet in diameter. The Iron-plate Committee, appointed by the British government to test the shot-resisting powers of various

styles of armor, conclude that their broadside ships cannot be made impregnable to modern artillery. The conclusion was sound, and had been drawn long before the Committee drew it by every engineer and artillerist who thoroughly knew his business and had given the subject attention. No vessel, say the Committee substantially, of the ordinary form, of any practicable size, can be made either impregnable or with an approach to impregnability.

It is a matter of demonstration that the English broadside system renders it imperative that their iron ships shall be huge, of deep draught, and consequently unwieldy. The ability of vessels to carry armor depends on the conditions which determine the carrying of any other load. This ability, of course, varies as the cube of the dimensions, while the area of the sides varies as the square of the dimensions. Hence, if we double the dimensions, we increase the displacement eight times, while the area of the sides increases only four times. It is easily seen, therefore, why these English broadside ships must be so large.* As with the Warrior, the first, so it is with the Northumberland, the last of them. The Warrior and Black Prince were fiercely assailed by a part of the British press, because they were only covered amidships with armor, both ends being left uncased. But the critics should have remembered that it was the fault of the system, not of the mechanics. The fact is, with a displacement of nearly ten thousand tons, these vessels could hold up an armor four and a half inches thick, with but eighteen inches of wood backing, over only seven thirteenths of their length. But the outcry was so great, that a desperate attempt was made with a new class, represented by the Northumberland, — a

* The admiralty writer in the Cornhill Magazine for February, 1861, says, "The enormous dimensions of the Warrior must have excited surprise," and then shows why "so large, and therefore so costly," a ship has been adopted. He says: "High speed had to be attained in combination with a shot-proof hull. Had not the proposal to leave the ends of the ship uncased been thought of, this combination would have been practically impossible, except with far greater dimensions than even the Warrior's; because the enormous weight of the armor would have required a corresponding displacement to support it; and this, again, would have needed still heavier engines to drive the ship through the water." See also the table from Norman Russell, and remarks by Scott Russell in the Artizan for 1862, p. 252.

gigantic vessel, only equalled in size by the Great Eastern. Yet, though she has upwards of ten thousand tons' displacement, she can only carry a complete armor of five and a half inches of iron and nine inches of wood. This latest fact in construction shows that an impregnable broadside iron-clad, of any dimensions at all practical, cannot be built. The great size and draught of those already built interfere with their usefulness.

Let us give some of the dimensions of the Warrior, the representative English iron-clad, as we did those of La Gloire, the representative French iron-clad. She is built of iron, with the exception of the deck plank and armor backing. She is 420 feet long over all; length between perpendiculars, 380 feet; breadth, 58 feet; tonnage, 6,177. But the ship ready for sea displaces nearly, if not quite, ten thousand tons of water, which is the total weight of the vessel. She is propelled by engines attached directly to the screw shaft. The cylinders are each 104 (effective) inches in diameter by four feet length of stroke. The boilers are of sufficient power to supply them with the quantity of steam necessary to develop about six thousand horse-power.

Having thus described the Warrior and La Gloire in detail, it only remains to append corrected lists of the English and French iron-clad fleets as they now stand, that at a glance may be seen the naval condition of those two countries.

One more step remained in naval warfare. It was taken at the advent of the Monitor. In 1861, the American Navy was in a critical condition. It is true, that it far surpassed the scanty flotilla of the Southern insurgents, and that it maintained a stringent blockade of the Southern coasts. But a new need quite as serious was pressing upon us. Foreign nations threatened to interfere in our civil war, and to take part with the insurrection. What had we to keep their fleets away from our shores? England and France were hurrying to completion enormous iron-armored vessels. Our navy was powerless to cope with these monsters. They alone, without the use of a single regiment, could have opened the Southern ports, and paralyzed our war-vessels. Our only resource against this threatening danger was to build a fleet of great iron-clads ourselves. Yet this resource was apparently not in our power. Our pro-

THE IRON-CLADS OF THE BRITISH NAVY.

	All Vessels Built and Building.									Side Armor and Casemate.								
Names of Vessels.	Tonnage.*	Length.	Beam.	Height out of Water.	Draught.	No. of Rifle Guns.	Kind and Size of Rifle Guns.	No. of Smooth Bores.	Kind of Smooth Bores.	Length of Casemated part.	Thickness of Armor-Plates.	Thickness of Backing.	Thickness of Skin.	Diameter of Cylinder.	Length of Stroke.	Indicated H. P.	Speed in Knots.†	Mean Draught.
		ft. in.	ft. in.	ft. in.	ft. in.		P'ndrs.		P'nd.	ft. in.	in.	in.	in.	in.	ft. in.			ft. in.
Warrior - - -	6109	380 0	58 4	20 0	26 3½	10 4	110 40	26	68	213 0	4½	18	9–16	104 effective	4 0	5471	14.4	25 11½‡
Black Prince - -	6109	380 0	58 4	20 0	26 9	11 4	110 40	26	68	213 0	4½	18	9–16	104 effective	4 0	5774	13.6	26 9½‡
Resistance - -	3710	280 0	54 1	18 2	24 10	6	110	10 2	68 32	143 0	4½	18	9–16	70¾ effective	3 6	2424	11.8	24 10½
Defence - - -	3720	280 0	54 2	18 2	24 11	6	110	10 2	68 32	143 0	4½	18	9–16	70¾ effective	3 6	2533	11.6	24 10
Hector - - -	4089	280 0	56 5	18 7	24 8	10	110	24	68	216 0	4½	18	9–16	82	4 0			
Valiant - - -	4063	280 0	- -	18 7	24 8	10	110	24	68	216 0	4½	18	9–16	82	4 0			
Royal Oak - -	4056	273 0	58 6	18 10	24 7½	11	110	24	68	All	4½	- -	- -	82	4 0	3703	12.5	24 8
Prince Consort -	4045	273 0	58 5	18 7	25 10½	11	110	24	68	All	4½	- -	- -	92	4 0	4234	13.1	24 8¼
Caledonia - - .	4125	273 0	59 2	18 7	25 10½	11	110	24	68	All	4½	- -	- -	92	4 0			
Ocean - - -	4047	273 0	58 5	18 7	25 10½	11	110	24	68	All	4½	- -	- -	92	4 0			
Royal Alfred - -	4045	273 0	58 5	18 10	25 7½	11	110	24	68	All	4½	- -	- -	82	4 0			
Zealous - - -	3716	252 0	58 7	18 0	25 3	12	110	8	68	103 0	4½	- -	- -	82	4 0			
Achilles - - -	6079	380 0	58 3½	20 2	26 3½	12	110	20	68	213 0	4½	18	9–16	104 effective	4 0			

Minotaur	6621	400 0	59 3½	20 2	25 8	12	110	26	68		5½	9	9–16	104 effective	4 4			
Northumberland	6621	400 0	59 3½	20 2	25 8	12	110	26	68	All except 24 ft. at the bow partially protected.	5½	9	9–16	104 effective	4 4			
Agincourt	6621	400 0	59 3½	20 2	25 8	12	110	26	68		5½	9	9–16	101	4 6			
Favorite	2186	225 0	46 9	14 1	20 5	10	110	- -	- -	66 3	4½	- -	- -	64	2 8			
Research	1253	195 0	38 6	12 0	14 0	2	110	2	68	34 9	4½	- -	-	50	2 0			
Enterprise	990	180 0	36 0	12 5	14 4	4	110	- -	- -	34 0	4½	- -	- -	45	1 6			
Royal Sovereign	3963	240 7	62 ½	9 7	22 11	5	12 Ton Guns.	- -	- -	All	5½	- -	- -	82	4 0			
Prince Albert	2529	240 0	48 0	8 6	20 0	Arma	ment not	decid	ed on.	All	4½	18	½	72	3 0			
Lord Warden	4067	280 0	58 9	18 9	25 3	36	110 or 68	- -	- -	All	4½ 5½							
Lord Clyde	4067	280 0	58 9	18 9	25 3	36	110 or 68	- -	- -	All	4½ 5½	- -	- -	116	4 0			
Bellerophon	4246	300 0	56 0	15 6	23 6	10 4	probably 300 110	- -	- -	90 3	6	10	1½	104 effective	4 0	- .	- ..	25 0
Pallas	2372	225 0	50 0	15 0	21 0	- -	- -	- -	- -	39 2	4½							

* Not the tons' displacement.

† Speed attained at the measured mile, in smooth water, with boilers new and free from scale, bottom of vessel clean, and with picked coal and stokers, conditions which cannot obtain in service. It is safe to deduct from 1½ to 2 knots for service speed.

‡ The draught of these vessels exceeded this at the trial.

N. B. The "length" given is in every case the length between perpendiculars. The "draught" is the mean load draught, taking the actual draught of ships completed and equipped, and the estimated draught for the others. The "length of the casemated part" is the length of protected battery.

The height out of water is measured at the top of the plank-sheer, and does not include the hammock berthing. In the Royal Sovereign and Prince Albert it is measured to the top of the deck only, as the bulwarks will be made to turn down. The two latter are "cupola ships," having each 4 cupolas, with armor 5½ inches thick, and a backing of 17 inches, and the skin 1½ inches.

The Warrior's cost was about $ 2,000,000; the Caledonia, Royal Alfred, and Lord Clyde, average $ 1,200,000. Blackwood lately declared that £ 40,000,000 (nearly $ 200,000,000) had been spent for the British iron-clad fleet.

THE IRON CLADS OF THE FRENCH NAVY.

Names of Vessels.	Displacement.	Length.	Beam.	Draught.	Thickness of Armor-Plates.	Thickness of backing.	Weight of Armor.	Nominal Horse-Power.	Speed in Knots.
	Tons.	ft.	ft.	ft.	in.	in.	Tons.		
*Magenta † §	6750	280	57	26	4 to 4½		900	1000	13½
*Solferino † ‖	6750	280	57	26	4 to 4½		900	1000	13½
Couronne (iron) ‡ §	6000	260	55	25	4½ to 3	15	700	900	13
Normandie †	5650	255	56	26	4½		800	900	13½
Invincible †	5525	255	56	25½	4½		800	900	13½
Gloire †	5650	255	56	25½	4½		800	1000	13½
Provence ‡	5700	260	56	25	6		1000	900	14
Heroine (iron) ‡	5700	260	56	25	6	15	1000	1000	
Savoie (building)	5700	260	56	25	6		1000	1000	
Revanche	5700	260	56	25	6		1000	1000	
Surveillante	5700	260	56	25	6		1000	1000	
Flandre	5700	260	56	25	6		1000	1000	
Guyenne	5700	260	56	25	6		1000	1000	
Gauloise	5700	260	56	25	6		1000	1000	
Valereuse	5700	260	56	25	6		1000	1000	
Magnanime	5700	260	56	25	6		1000	1000	
Taureau	2450	200	47½	16	4½		800	1000	
Belliqueux	3350	230	40	19½	6		800	900	

* 52 breech-loading rifle-guns 6.4 inches calibre; a gun corresponding in power to the 100-pounder Armstrong.

† Carries the guns 5.9 feet from water-line. Armored at the water-line, and over that portion in which the guns are placed. Bows and stern above water-line unprotected.

‡ Carries the guns 6.4 feet from water-line. Protected at the water-line and over the battery after the manner adopted by Mr. Reed in the English Navy.

§ Turned in a circle of 976 feet radius, according to M. Raymond.

‖ Turned in a circle of 1216 feet radius, according to M. Raymond.

N. B. This Table, although meagre, gives an accurate idea of the capabilities and power of these vessels. The principal dimensions and thickness of armor are correct. Various sources of information have been compared, and they have been found to agree on these points.

The cost of the French iron-clads was: — Magenta and Solferino, 12,000,000 francs each; Couronne, Normandie, Invincible, Gloire, Provence, Heroine, 7,000,000 francs each.

In a recent letter to the London Times, M. Dupuy de Lôme, the designer of the French iron-clads, unintentionally furnished evidence that the speed of these vessels has been greatly overrated.

spective iron-fleet must, of course, have equalled in invulnerability the Transatlantic La Gloires and Warriors. But we have already shown that equal invulnerability on that plan demands equal dimensions. Let the reader, then, with pencil in hand, estimate how long it would have taken our government to build a dozen Warriors,—iron vessels of magnitude only excelled by the Great Eastern! Let him consider how few establishments could have essayed to build such vessels at all, with our deficiency in the appliances and experience of iron ship-building, and the narrow limits of the labor available for such work. A full half of the builders employed in constructing the iron-clads which we actually used, drove their first rivet after the war broke out; and we honestly believe an American fleet of Warriors would not have been completed up to this day.

Cost, too, was as worthy of consideration as time, in the projected iron-clads. The Warrior cost immense sums of money; but it would have cost even one half more in America. When, in the fall of 1862, we were threatened by the Navy Department with two seven-thousand ton iron-clads, three bids for their construction were received, of which two were precisely the same, namely, $4,200,000 for each vessel; and at that time gold was only at about 130. How many such vessels we could afford to build, especially when gold began to rise in value, was a pretty serious question in the state of our national finances. Before they were finished, these vessels would have cost seven millions apiece. But, again, if such a fleet of broadside iron-clads could have been afforded, and could have been constructed in season (as it could not), it would have left us only on equal terms with foreign powers; and of what use, meanwhile, would it have been for our immediate necessities? Their great draught of water (as the table of British iron-clads will show) would have made them useless as blockaders, nor could they have operated in any way against the Southern ports. Of what use would it have been to us, so far as hemming in the Rebellion was concerned, if Great Britain had presented to us three years ago her whole fleet of titanic iron-clads? They could scarcely approach within sight of our coast, from Cape Henry to Key West. If kept in commission at all, it would have taken a numerous army of

sailors to man them, to say nothing of other expenses. The most judicious and practical use of such a magnificent gift (if we had only had a navy-yard with sufficient depth of water) would have been to put the whole fleet in ordinary. The man who drew the elephant at a raffle is the only one whose experience would have been worth our consulting.

Such was the national dilemma at the outbreak of the war; and there was ample reason for alarm and despondency. Above all, the Navy Department, well knowing that iron-clads of some sort must be instantly built, was sorely perplexed. The inapplicability of the European system of broadsides to our needs — from their great draught, enormous size, unwieldiness, great cost, time required in building, and their vulnerability, after all, to heavy guns — was well understood by the Secretary and his practical Assistant. The iron-clads proposed, we could hardly afford; they could not be got ready for service for years; and, when ready, they would be unfit for their purpose. The Southern harbors in which large iron-clads can manœuvre are very few; and though the draught need not be increased proportionally to the length, yet, with a model even just tolerable, a seaworthy vessel can neither be very shallow nor indeed very flat-bottomed. At this crisis in our national destiny appeared the solution of the momentous problem, and a solution complete and perfect, — the American Monitor. This invention instantly neutralized the aggressive power of the English and French monster iron-clads. Time, expense, adaptability, invulnerability, — everything was met and made plain. We were able to launch, in an incredibly brief time, iron-clads of *one eighth* the Warrior's displacement, at *one eighth* of her cost, with much less than *one half* her draught, yet with double her invulnerability and a battery far surpassing hers in power. A complete cuirass of armor protected every part, and within could be mounted and handled guns of twenty tons; while the heaviest guns even yet in service in either the English or French navy do not weigh more than six tons, and their use is attended with difficulties.

The Monitor was an original invention of Captain Ericsson.*

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* Inquiry into the Origin and Qualities of the Turret System. London: Longmans, Green, & Co. 1866.

The first vessel was built in one hundred days. And when we consider that, although the design had long been familiar in the brain of its inventor, it was entirely novel in every part, and was fairly made up of innovations on tried models; that many diverse inventions, each complete in itself, were combined in it; that every part was arranged with such precision that it worked to perfection; and that its mechanical construction had to be conducted absolutely without the aid of experience and experiment, — this must be pronounced one of the most marvellous achievements in the mechanics of naval warfare. The principle on which the original Monitor was constructed has since been adopted, without any alteration whatever, for all succeeding monitors, whether of wood or iron. The only changes have been in matters of detail, with regard to which, of course, on account of the haste of the original construction, there was opportunity for improvement. The conception of a turreted iron-clad, however, is far inferior to the task involved in carrying out all its details to successful operation. The most distinctive feature of the monitor iron-clad is in building her so low in the water that the waves, instead of devoting their strength to beating against her sides, may flow over her, powerless to inflict injury. Next to that is undoubtedly the turret. This turret is simply a cylindrical gun-shield, with the machinery that revolves it so protected as not to be disarranged by the impact of hostile shot. Only one piece of the revolving machinery is attached to the turret; and of this alone, of course, could injury be predicated. This piece is a cog-wheel, about seven feet in diameter, without arms, and bolted to the four wrought-iron gun-slides and the large wrought-iron cross-beam running at right angles to these. This beam has a large eye in the centre, which fits over a heavy wrought-iron stationary shaft resting on the bottom of the vessel. The under side of the eye rests on a collar forged on this shaft. Hence the periphery of the cog-wheel is at least seven feet from the outer circumference of the turret, — the whole diameter of the latter being upwards of twenty-one feet. Of course, no blow delivered on the exterior of the turret can damage this machinery.

But cannot shot, striking at the base of the turret, impede

its revolution? They cannot. A broad, polished, flat ring is planted in the deck, whereon the turret-base, which is another polished flat ring, revolves. These rings are two or three inches wider than the thickness of the turret. The result is a water-tight joint; and a safe revolution is guaranteed by the absence of any flanges or other obstructions against which the turret can be jammed by the impact of hostile shot. English observers usually think that the key, or wedge, situate underneath the stationary central shaft, is designed to lift the turret, so that it will revolve on this as its central axis; but in fact the key is only designed to relieve slightly the weight of the turret on the broad, flat ring on which it turns. Its purpose is merely to sustain part of the weight of the guns, gun-carriages, and pilot-house. Lifting the turret from the deck would not permit it to be revolved with the steadiness necessary for the accurate aiming of the guns; and besides, the dirt would wash in between the turret and the deck, and the rings already described would not form a water-tight joint. The writer has sufficient reason to believe that Ericsson's own idea of a perfect turret, as regards its revolving qualities, is one unprovided with any means of lifting the central stationary shaft, and one revolved by engines so powerful and gearing so strong as to turn the turret with the whole superincumbent weight of turret, guns, and gun-carriages.

To an unprofessional observer the monitor iron-clad appears to be a simple structure, a single conception, the product of a single application of inventing power. Even in this light, however, there is something æsthetically satisfactory in the appearance of the monitor. It is a long, black line, placidly recumbent, with a great cylinder bolt upright in the centre. "An ugly customer, — a hard thing to hit," is the involuntary comment. But when one who understands the phenomenon explains its interior mechanism, he will have to recount at least twoscore separate and distinct inventions, each of which is worthy of high praise. Such a recital never having been made, let us briefly mention several of the more important.

The ruling idea of the monitor is the concentration of guns and of armor, — of both the offensive and the defensive power. This idea involves enormous guns. Enormous guns involve

the necessity of the mechanism suitable for handling them. Thence the invention of the beautiful wrought-iron gun-carriages; and again the mechanical appliances for running the guns in and out; and finally the new compressor-gear for taking up the recoil. When we reflect that the service-charge of the 15-inch gun is sixty pounds of powder, it will be seen what the duty is which is thus imposed on all parts of this magnificent apparatus.

Next we come to the port-stopper. The problem of closing gun-ports, on the withdrawal of the piece for reloading, so as to prevent hostile shot from entering at the aperture, is one which has engaged the attention of artillerists for a great many years. In the monitor this is accomplished by a curved forging of wrought-iron, of the same thickness as the turret. It is supported at top and bottom, and so accurately pivoted and balanced, that, though it weighs several tons, one man can easily close it. We are free to pronounce this one of the neatest of the lesser features of the monitor. Next comes the pilot-house. Where shall this be placed? Obviously not on the deck, as it would interfere with the horizontal sector of fire of the guns in the turret. Its only possible position is on the top of the turret itself; and there accordingly it is placed. But the turret in action may be required to be revolved, while the pilot-house must be kept stationary. A new contrivance at this point becomes necessary. This is accomplished by a central column of wrought-iron, around which the cylindrical turret rotates, and to the top of which the pilot-house is firmly secured. But may not the steering gear of the vessel, which is in the pilot-house, be disarranged on its perch? This danger is obviated by burying the rods of the gear in the central column. In the heavy monitors the pilot-house is of iron, upwards of twelve inches thick, and beyond the danger of piercing by any artillery now in use. But lest, by remote possibility, any accident should happen to the pilot-house, another provision for steering is fixed underneath the turret, for use in case of need.

As the turret weighs, in any monitor, several hundred tons, an extraordinary foundation must be provided for it. This foundation consists, first, of the enormous wrought-iron bulkheads, a little less distance apart, in a fore-and-aft direction,

than the diameter of the turret. To these are riveted two similar bulkheads at right angles to the others, and about the same distance apart. The whole forms a hollow, massive, rectangular column, extending the whole depth of the vessel, and not only holding up the turret with ease, but making the vessel itself inconceivably strong; and it may be added, that within this impregnable column are the turret-gear and the engines for turning it by steam-power.

We might go still further into details with regard to the turret and the method of putting it together. We might speak of the novel construction of the side-armor, and the extremely ingenious anchor-well, and the excellent ventilation.* But we pass to the general stern arrangements of the rudder and propeller. So perfect was this latter arrangement that Mr. E. J. Reed, the Chief Constructor of the British Navy, adopted it entire in the Bellerophon, with scarcely an alteration in detail. The consequence is that the Bellerophon is the only iron-clad in the British Navy which can be steered well. The others are all handled with great difficulty. As one illustration, on the trial trip of the Minotaur, it required at one time forty-eight men at the wheel and the tackles connected therewith.† The English authorities are very naturally delighted with the steering arrangement of the Bellerophon, as the reports of the press amply show.

Nothing, however, in this combination of inventions attracts more admiration than the daring novelty of constructing a vessel purposely so low in the water (for none of the monitors rise

* "It is gratifying to know that an examination of the sick reports, covering a period of over thirty months, shows that, so far from being unhealthy, there was less sickness on board the monitor vessels than in the same number of wooden ships with an equal number of men, and in similarly exposed positions. The exemption from sickness in the iron-clads is in some instances remarkable. There were on board the Saugus from November 25, 1864, to April 1, 1865, a period of over four months, but four cases of sickness (excluding accidental injuries), and of these two were diseases from which the patients had suffered for years. In the Montauk, for a period of one hundred and sixty-five days prior to May 29, 1865, there was but one case of disease on board. Other vessels exhibit equally remarkable results; and the conclusion is reached, that no wooden vessels in any squadron throughout the world can show an equal immunity from disease. The facts and tables presented are worthy of careful study." —Extract from the Report of the Secretary of the United States Navy to Congress, respecting the Health of the Fleet.

† See London Engineer.

more than eighteen inches above the water-level) that the waves may roll over her, and surrounding her with a projecting riband or belt of armor and backing. 1st. It prevents rolling, except through a very few degrees, by allowing the waves to flow over the deck instead of rising against a high side. This steadiness is assisted by the wing-like projections. While such iron-clads as the Warrior would be rolling their unprotected portions fairly out of water, and to such an extent that no accurate gunnery could be thought of, the Monadnock would ride almost motionless, and could aim her heavy guns with perfect ease. 2d. By reducing the area to be protected, it makes the thickness of armor (i. e. impregnability) the maximum. 3d. It reduces the target for the enemy to aim at to the minimum. The only marks are an iron-bound impenetrable strip of hull a few inches high, an impregnable turret, a smoke-pipe, and perhaps an air-trunk. 4th. It permits the iron armor to add to its enormous oak backing the entire thickness of the deck. This deck consists of enormous beams extending entirely across the vessel just above the level of the water-line, on which again is a layer of heavy beams covered with the iron deck-plating.

We have now examined, from a mechanical point of view, the two rival systems of iron-clad vessels. A brief comparison will illustrate their comparative merits. The Bellerophon is, beyond all comparison, the finest and most powerful broadside iron-clad ever built. Imagine her entire broadside (which will consist, if the Admiralty ever get the carriages to mount them, of five $10\frac{1}{2}$-inch 12-ton guns) concentrated in two guns, mounted within a revolving cylinder of wrought-iron at least fifteen inches thick and absolutely impregnable. This tremendous ordnance is capable, as actual experiments demonstrate beyond the shadow of doubt, of at once smashing large holes through the thinly clad sides of any broadside vessel ever yet built, or which ever can be built. Yet it can be accurately aimed *directly ahead*, (in which, of course, it has an inestimable advantage over the broadside,) or to any point in the horizon, by the hand of a child, by mere pressure on a handle in the rear of each gun. Our revolving, impregnable cylinder, and its irresistible battery, are then put into a hull

just peering above the water, and offering no hopeful mark to an adversary. If one of his shot should strike it, it would strike a hull protected from end to end with ten and a half inches of wrought-iron armor, backed with three or four feet of oak, nay, with the entire deck itself. Those vital organs, the propeller and rudder, are as completely protected as the guns themselves. Such is the Dictator, and such the Dictator class of American monitors.

No possible doubt can exist as to the result of a tourney between the Dictator and the best broadside iron-clad yet constructed,—let us say the Bellerophon, the masterpiece of broadside iron-clads. Besides all the advantages already named, the former could take any desired position, and keep close under the stern or lap the sides of her antagonist for nearly seventy feet, over which whole distance the Bellerophon has no armor at all except at the water-line. The Bellerophon would not be able to bring a single gun to bear on her antagonist. Even if she could, it would require the utmost delicacy of accurate practice to hit the low line of the monitor; and if she were hit, it would be like blowing peas at an alligator. And all this, even, supposes a calm sea, when the broadside vessel would not roll. Meanwhile, from her impregnable turret, the Dictator would hurl projectiles which would riddle the unarmored parts of the Bellerophon like a sieve, and against which even her armor would be of no avail.*

The 15-inch guns, weighing nearly twenty tons, have now frequently been handled in actual battle in the monitor turret, and one word will suffice to show how completely any broadside vessel is at our mercy. In the experiments with the 15-inch smooth-bore, a solid shot, with sixty pounds of powder, hurled against the famous 6-inch solid French plate of Petin and Gaudet, completely perforated it. The verdict was, "Target completely penetrated and badly smashed." † But we do not stop here. The Puritan will be armed with a pair of 20-

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* As the displacement of the Bellerophon is upwards of 7,000 tons, and that of the Dictator but little over 4,000, a simple calculation shows that, if the displacement of the latter should equal that of the former, the Dictator's entire side-armor would then be fully thirteen inches thick, and the turret upwards of twenty-four inches.

† Holley on Ordnance and Armor, p. 190.

inch guns, weighing nearly fifty tons each. These unprecedented and almost appalling guns can be worked in the monitor turret more easily by steam-power than Nelson worked his 24-pounders. The service charge of the 20-inch gun will be at least one hundred and thirty pounds of powder, and the shot weighs one thousand pounds. The motion of the vessel is never such as to render the gun unmanageable, while its armor completely protects it. This is the system which the wise men of England and France have contemptuously treated as "a practical mistake"!

The following table is prepared for the purpose of showing what the monitor system has produced, or is producing, for the United States.

Class and Number.	Tonnage.	Draught of water.		Thickness of armor.	Backing.	No. and thickness of turrets.		Number and size of guns.	
		ft.	in.	in.	in.	No.	in.	No.	in.
Passaic class (9), for harbor defence,	844	10	9	5	36*	1	11	2	15
Monadnock class (4), for coast defence,	1564	13	0	6	37*	2	$10\frac{1}{2}$	4	15
Kalamazoo class (4),	3200	18	0	14	40*	2	15	4	15†
Canonicus class (9), for coast defence,	1034	12	2	$9\frac{1}{2}$	28*	1	$10\frac{1}{2}$	2	15
Light draught class (20), built for special service in shallow rivers, &c.,	614	6	9	3	42*	1	8	2	11
Puritan,	3265	20	0	$10\frac{1}{2}$	48*	1	15	2	20
Dictator,	3033	20	6	$10\frac{1}{2}$	48*	1	15	2	15

The monitor is the complete aud positive solution of the great naval problem of the age. Since no further concentration of armor is possible, it has reached the maximum of impregnability. Since guns of any weight can be carried, handled like toys, and shielded in an impregnable turret, the aggressive power has reached the maximum which gunsmithery has yet accomplished. Since the Monadnock has exchanged salutes with the Moro, touched at Buenos Ayres, passed through Magellan Straits, and anchored off Valparaiso, and the Miantonomoh visited Halifax on her way to England, to say nothing of coast voyages for four years, — the cries against the "seagoing" qualities of the monitors may be considered over. In-

* Besides the entire width of deck. † 20-inch guns may be mounted.

deed, this monitor, being an invention radical in its nature and fortified by first principles, admits of no change.*

It may have been expected that, in our discussion of the mechanics of modern naval warfare, we should touch upon rams and torpedoes. Want of space must be our plea for failing to do so. However, it may in general be said, that the experience of our war has diminished the high hopes once entertained of the ram-power in warfare. Two conditions are indispensable to success. The first is an attack at high speed; the second, a concussion at right angles. Now, so much time is usually required in producing these two conditions, that, meanwhile, an alert antagonist is prepared to neutralize them. As to torpedoes, we believe they are destined to play a momentous part in the warfare of the future. Their power has hardly begun to be developed. We pause, however, with this declaration of belief, and do not descend to the depths of possible submarine warfare.

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* The qualities which seem to be indicated for a solution of the problem of a complete iron-clad are the maximum thickness of armor which can be had with the minimum displacement, together with the ability to handle guns of the most powerful description, to point them with facility directly ahead, or to any other point in the horizon, and, of course, to have them completely protected. In a word, the solution of the problem indicates concentration of both armor and battery, of offence and defence; and, other things being equal, the vessel which carries this concentration to the greatest extent will be relatively the most powerful. These indispensable conditions can only be satisfied by the Ericsson system; for, as Commodore Rodgers graphically expresses it, "The monitor has the least possible surface to be plated, and therefore takes the least possible tonnage to float armor of a given thickness, or, with a given tonnage, allows the greatest possible thickness, and consequently the greatest possible impenetrability. The ability to carry armor is proportionate to the tonnage; but the Monitor of 844 tons has actually thicker plating than the Ironsides of 3,480 tons, or than the Warrior of 6,000 tons; and yet the Ironsides and Warrior have only the middle portion of their hulls plated, their ends being without armor."

The following calculation will show the enormous dynamic power of a 20-inch shot moving at the velocity of 1,213 feet per second, which is the velocity given by only 100 pounds of powder. This velocity is acquired by a free fall through the height of 22,990 feet; this multiplied by 1,000 pounds, the weight of shot, gives a dynamic force of 22,990,000 foot-pounds. "Let us suppose an armor plate, eight inches thick, composed of iron possessing a tensile strength of 50,000 pounds to the square inch, to be struck by a 20-inch spherical shot — weight 1,000 pounds — with a velocity of 1,213 feet per second. The greatest amount of force needed to destroy the supposed plate, under any possible circumstances, will be that corresponding with the tensile strength of an iron bar, the cross-section of which represents equal to that of a cylinder eight inches long, multiplied by the circumference of a cylinder twenty